DOCUMENT RESUME

ED 241 798 CE 038 661

AUTHOR Morrison, John E.; Goldberg, Stephen L.
TITLE A Cognitive Analysis of Armor Procedural Task Training. Technical Report 605.
INSTITUTION Army Research Inst. for the Behavioral and Social Sciences, Alexandria, Va.
PUB DATE Mar 82
NOTE 28p.; Prepared at ARI Field Unit, Fort Knox, KY.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Job Skills; Job Training; *Learning; Learning Processes; Memory; *Military Training; *Recall (Psychology); Retention (Psychology); *Skill Development; Vertical Organization
IDENTIFIERS Army

ABSTRACT

Traditional and performance-oriented approaches to procedural training were compared, and the deficiencies were identified. A cognitive interpretation of procedural learning was advanced, and training implications were considered. Representative armor procedures were analyzed to derive the underlying memory structures required for recall. Findings indicated that memory for armor procedural tasks can be represented as hierarchical structures of task goals, that the hierarchical structures have implications for procedural training, and that further research should be addressed to verification of the structures using actual soldier performance. Training applications of the memory structures that were suggested included a "part-task" training strategy that allows soldiers to organize procedural elements into appropriate subgoal units and training of soldiers to associate subgoal names with the appropriate subprocedures. (Hierarchical structures for armor tasks are appended.) (YLB)

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Technical Report 605

ED241798

A COGNITIVE ANALYSIS OF ARMOR PROCEDURAL TASK TRAINING

John E. Morrison and Stephen L. Goldberg

ARI FIELD UNIT AT FORT KNOX, KENTUCKY

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March 1982

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report 605	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A COGNITIVE ANALYSIS OF ARMOR PROCEDURAL TASK TRAINING		5. TYPE OF REPORT & PERIOD COVERED Technical Report 6. PERFORMING ORG. REPORT NUMBER --
7. AUTHOR(s) John E. Morrison and Stephen L. Goldberg (ARI)		8. CONTRACT OR GRANT NUMBER(s) --
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA 22333		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q263743A794
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue Alexandria, VA 22333		12. REPORT DATE March 1982 13. NUMBER OF PAGES 24
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) --		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE --

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

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18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Armor	Memory	Radio Equipment
Army Training	Retention (Psychology)	
Learning	Machineguns	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Traditional and performance-oriented approaches to procedural training were compared, and their deficiencies were noted. A cognitive interpretation of procedural learning was advanced and training implications were discussed. Representative armor procedures were analyzed to derive the underlying memory structures required for recall. Specific training applications of the memory structures were also discussed.

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5001 Eisenhower Avenue, Alexandria, Virginia 22333

Office, Deputy Chief of Staff for Personnel
Department of the Army

March 1982

Army Project Number
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FOREWORD

The Fort Knox Field Unit has a long history of applying behavioral research methods to problems in armor skill performance. As a part of this effort, the Weapon System Training Team is charged with research and development of methods for training armor tasks.

Because of the importance of procedural skills to the operation and maintenance of armor systems, procedural training methods must be scrutinized to ensure that soldiers are getting the best instruction available. The authors of the present research compared the traditional lecture and current performance-oriented approaches and concluded that both approaches had weaknesses. They then examined current cognitive conceptions of procedural learning and derived training strategies that address these weaknesses. To illustrate the cognitive concepts, they analyzed some representative armor procedures and derived some training principles from the analyses.

This research is of interest to those training researchers and developers who are exploring alternative training methods. Although the example tasks are armor procedures, the concepts should apply to training on other types of procedures as well.

JOSEPH ZEIDNER
Technical Director

A COGNITIVE ANALYSIS OF ARMOR PROCEDURAL TASK TRAINING

EXECUTIVE SUMMARY

Requirement:

Both traditional lecture and performance-oriented approaches to procedural training are deficient in some respects. Current cognitive theories of learning and memory should be used to develop alternative strategies for training procedures.

Procedure:

Representative armor procedures were analyzed for the memory structure underlying procedural task performance. Three assumptions about learning and memory guided the analyses: (a) Memory for a procedure is organized around task goals, (b) the organization is hierarchical in form, and (c) each hierarchical node is limited to no more than five subordinate branches.

Findings:

1. Memory for armor procedural tasks can be represented as hierarchical structures of task goals.

2. The hierarchical structures have implications for procedural training.

3. Further research should be addressed to verifying the structures using actual soldier performance.

Utilization of Findings:

The present research should be of interest to those training researchers and developers who are exploring alternative training methods. In addition to providing a model of procedural memory, the task goal structures are also potential training aids.

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A COGNITIVE ANALYSIS OF ARMOR PROCEDURAL TASK TRAINING

INTRODUCTION

Traditional and Performance-Oriented Approaches

Prior to the early 1970s, procedural training in the military followed the traditional academic model of instruction. That is, instruction consisted mostly of formal lectures on general theoretical principles of equipment operation. Supporters of the traditional approach maintained that the theoretical background deepened the novice soldier's understanding of the task and the equipment. However, there were several serious problems with applying this approach in the context of entry-level military training. In particular, the soldier did not always understand the abstract theoretical concepts. Also, trainers often failed to relate the theory to appropriate entry-level jobs or tasks. The lecture format itself was an impediment to learning in that it encouraged passive listening rather than the active practice required to attain task skill.

As a reaction to the deficiencies of the traditional approach, the Army developed and implemented a different method of instruction called "performance-oriented" training (FM 21-6). This approach is based on a thorough job and task analysis that identifies job tasks, conditions under which the tasks are performed, training requirements, and on-the-job standards of acceptable performance. Instruction is then designed to impart only those task knowledges and skills necessary for the soldier's assigned job. Most important, the performance-oriented format is devoted to short demonstrations and hands-on practice, rather than lectures. To train a soldier in a procedural task, the performance-oriented instructor starts by demonstrating the steps involved in the task. Most of the training time is then devoted to practice on the operational equipment. During this phase, the soldier repeatedly executes the task until he or she meets task standards. Verbal explanations are mostly limited to the mechanics of task performance (the "hows"), with little or no time given to explain the meaningful task goals (the "why"). According to the performance-oriented approach, then, practice can be characterized as a rote process that does not involve conceptual task knowledge.

The performance-oriented emphasis on practice is congruent with the commonly held assumption that learning requires repeated exposures to the task to be learned. One way in which researchers have analyzed the effect of repetition is to examine learner processes that occur during practice. A general finding is that long-term retention is associated with semantic (i.e., conceptual or meaningful) coding of the task to be learned (e.g., Bjork, 1975; Craik & Lockhart, 1972; Melton & Martin, 1972). In order to remember a task, learners must abstract out and interrelate its meaningful aspects. The rote quality of practice in the performance-oriented approach places the burden of semantic task coding on the learner. Given the varied aptitudes and backgrounds of soldiers, we would expect the effectiveness of learner coding to range from appropriate to inappropriate. To ensure sustainment of procedural skills, trainers should provide a reasonable coding scheme rather than rely on soldiers' learning strategies.

Skill sustainment is an increasingly important Army training issue. One of the central problems is that soldiers have relatively few opportunities to practice their job skills. Civilian workers (e.g., assembly-line workers) repeat their job tasks over and over, resulting in increases in task skill over time. In contrast, soldiers--particularly those in the combat arms--practice their job skills only during infrequently held field exercises or actual combat. Research has shown that procedural skill performance rapidly declines without intervening practice (e.g., Shields, Goldberg, & Dressel, 1979; Osborn, Campbell, & Harris, 1979). Given the Army's limited resources to provide regular practice, the effectiveness of initial training becomes that much more critical. Training developers must design instructional strategies to prolong skill sustainment over periods of no practice.

To summarize, we have compared traditional and performance-oriented procedural training and found problems with both approaches. The traditional lecture method was too theoretical, without enough emphasis on performance. Performance-oriented training, in contrast, was conceptually barren, to the possible detriment of task retention. A better approach lies between these two extremes. That is, procedural training should be both conceptual and performance oriented.

A Cognitive Interpretation of Procedural Learning

Over the past 30 years, significant progress has been made in defining and identifying the cognitive structures and processes that underlie human learning and memory. In this section, we describe some of these theoretical concepts that are specifically related to procedural skill acquisition and sustainment.

One of the maxims of cognitive psychology is that human beings are limited information processors. For instance, research indicates that our immediate memory for sequence is limited to 4 ± 1 items (Johnson, 1970). Given this constraint, how do people remember long procedures? In a pioneering paper, Miller (1956) suggested that we can overcome the limitations of immediate memory by recoding items to be learned into larger units, or "chunks." Each chunk can be represented by a single code, thereby effectively reducing the memory load. Even larger chunks can be formed by combining first-order chunks into higher-order units (Mandler, 1967). However, because of the limits of immediate memory, each chunk can consist of no more than five subordinate units, be they single items or lower-order chunks. This hierarchical organization of memory codes not only provides an economical scheme for storing items in memory, but also represents a "plan" for retrieving the information at recall (Miller, Galanter, & Pribram, 1960).

Often-cited evidence for the chunking process is the strong tendency of learners to cluster categorically related items during free recall of verbal lists (e.g., Bousfield, 1953). The clusters reflect the learners' use of semantic relations between items to organize their memory for the list. We suggest that soldiers similarly organize their memory for armor procedures

around the task goal and subgoals.[1] Thus, the task goal structure corresponds to the semantic relations in verbal lists. The hierarchical goal structure for a hypothetical procedure is shown in Figure 1. At the top of the figure is the overall task goal. Below that are two levels of subgoal organization that are distinguished by the terms "strategies" and "tactics" (Miller et al., 1960). Strategies refer to high-order nodes oriented toward general or abstract subgoals, whereas tactics are low-order subgoals related to immediate and specific task objectives. At the lowest level are the individual task elements that comprise the procedure.

There is evidence that knowledge of task structure enhances both verbal (Bower, Clark, Lesgold, & Winzenz, 1969) and motor (Diewart & Stelmach, 1978) retention. Presumably awareness of the task structure aids the learner in organizing and coding input in a reasonable and efficient manner. Thus, the hierarchical structure of task goals not only provides a model of procedural memory organization, but also provides a potential aid for promoting skill sustainment. However, this generalization is based on research using artificial laboratory tasks with experimenter-imposed structure. The structure of a real-world procedure, in contrast, is intrinsic to the logical and mechanical constraints of the task. The next section presents a method for deriving the goal structures of actual procedures using armor tasks as examples.

ANALYSES

Tasks

Procedural tasks were defined as those accomplished by a series of steps usually performed in a fixed sequence. Of present interest were tasks that soldiers typically perform from memory, i.e., without benefit of job aids. Using these criteria, two subject areas were chosen from the Armor One Station Unit Training (OSUT) Program of Instruction: the M240 coaxial machinegun and the AN/VRC tactical FM radio. Specific task descriptions follow.

a. Clear the M240. The object of clearing is to unload the weapon and place the bolt in its forward (safe) position.

b. Load the M240. The purpose is to insert ammunition into the weapon in order to fire it.

c. Immediate Action on the M240. Immediate action is the loader's response to announcements of stoppage in firing caused by some weapon malfunction.

d. Disassemble the M240. The object of this task is to field strip the weapon for periodic maintenance.

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[1] The goal orientation of our proposed model of procedural learning has much in common with Newell and Simon's (1972) approach to problem solving. Indeed, Voss (1979) and others have recognized that learning and memory tasks require problem-solving skills. Still others (e.g., Abelson, 1981) have argued that goal hierarchies are fundamental knowledge structures applicable to a variety of cognitive processes.

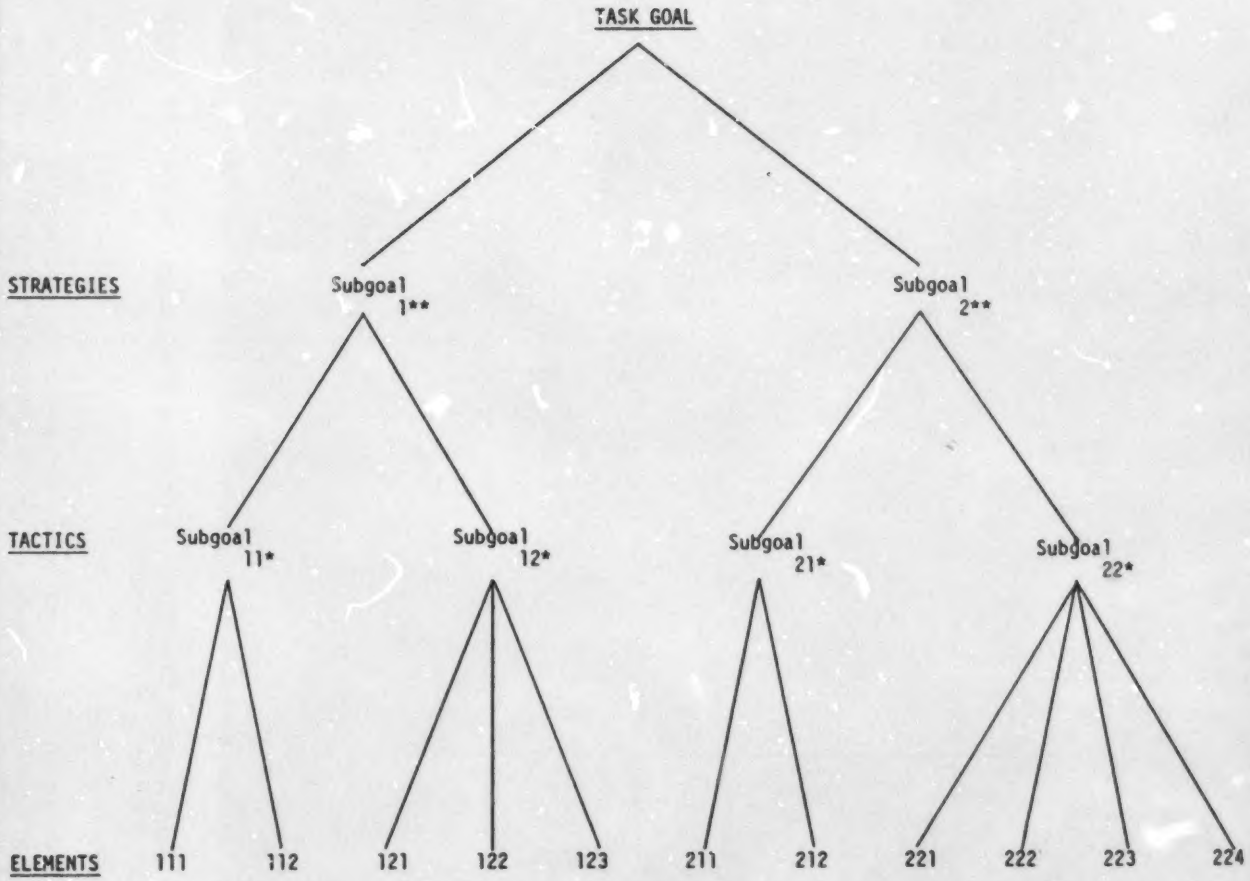

Figure 1. Hierarchical goal structure for a hypothetical procedure.

e. Assemble/Functions Check the M240. For this task, the soldier reassembles the field-stripped weapon, then checks the operation of the weapon to determine if it is properly assembled.

f. Operate the AN/VRC-64. The goal of this task is to ready the tank intercom and radio-transmitter for operation.

Procedure

The first step in the analytic process was to identify the task elements of each procedure. Task elements were defined as the temporally discrete and reliably observable behaviors required for the proper execution of procedures. The primary sources of task information were technical manuals for the AN/VRC-64 (TM 11-5820-498-12) and the M240 (TM 9-1005-313-10). Additional task information was obtained from the Soldier's Manual for the Armor Crewman (FM 17-19E1/2) and observations of soldiers in Armor OSUT.

Consistent with our model of procedural learning and memory, three rules were followed for deriving the task structure: (a) The organization must be strictly hierarchical with no overlapping relations or cross-classifications, (b) each hierarchical node and its subordinate branches must relate to some meaningful objective, (c) each node can consist of no more than five branches.

The general format for the task hierarchies was a four-level structure as illustrated in Figure 1. Construction of hierarchies was accomplished by a combination of "top-down" and "bottom-up" analyses. From the top, the overall task goal was segmented into intermediate strategic subgoals. From the bottom, task elements were grouped into meaningful tactical subgoals. The strategic and tactical subgoals were then related to one another, the result usually requiring modifications to the initial top-down and bottom-up analyses. Also, because of the limitations to the number of branches per node, some longer tasks required an additional level of tactical subgoals. Every hierarchical node was labeled with a verb or verb phrase descriptive of the subgoal functions.

The derivation of the hierarchical structure for Clear the M240 (Figure 2) is described in detail below to illustrate the analytic process. The hierarchical structures of the remaining tasks are presented in the Appendix.

Analysis of Clear the M240

Analysis showed that the overall goal of Clear the M240 was to put the weapon into a state that prevents accidental discharge. The overall goal was simply represented by the term "CLEAR" in Figure 2. The overall task goal was then parsed into two strategic subgoals: "Unload" and "Return." The object of the Unload subgoal was to remove all sources of ammunition from the weapon. The purpose of the Return subgoal was to restore the weapon to a safe state after unloading.

From the bottom of the figure, pairs of elements were joined because of a few mechanical constraints of the M240. One of the constraints was that the

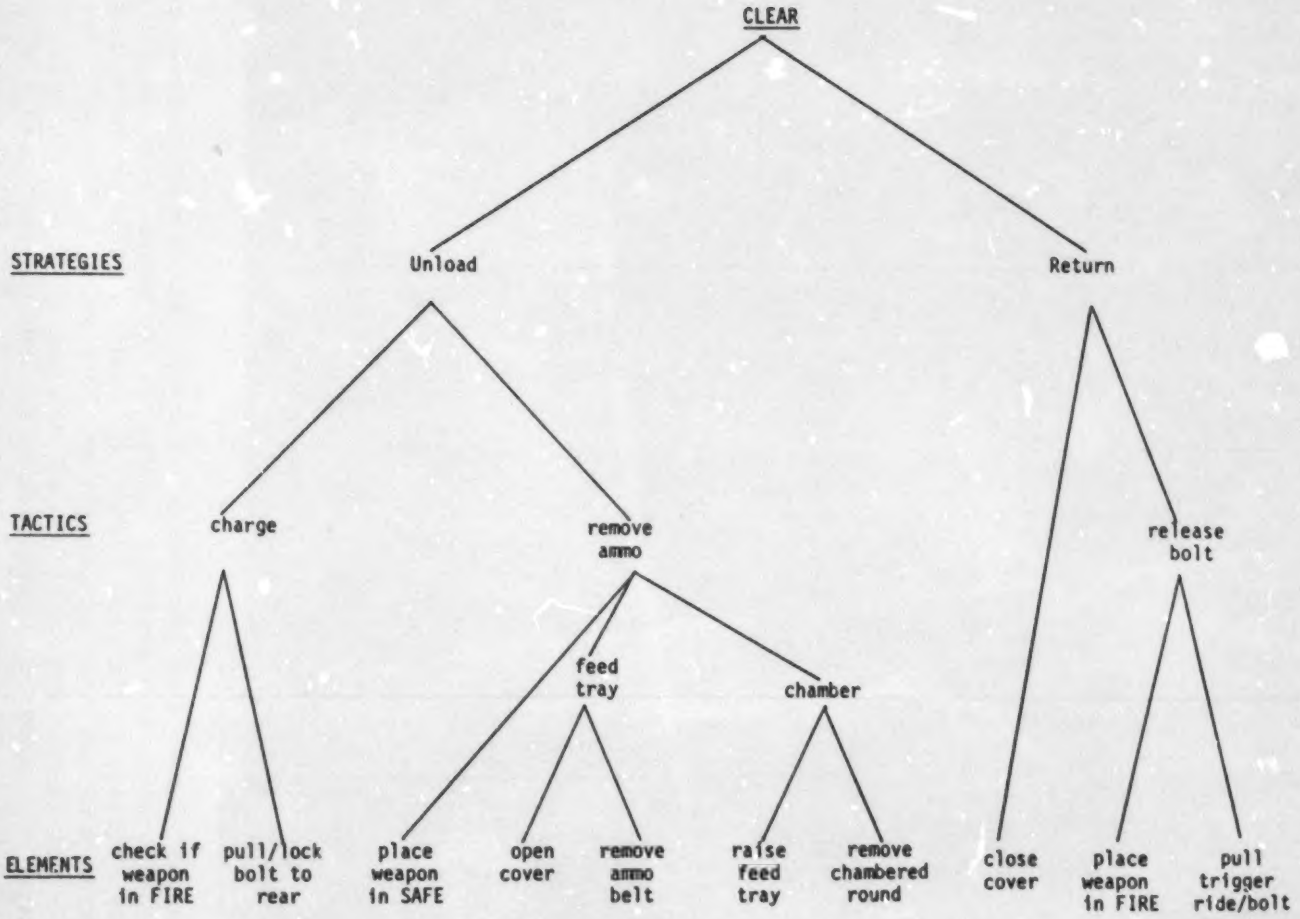

Figure 2. Hierarchical goal structure for Clear the M240.

safety must be in FIRE in order to move the bolt forward or backward. Thus, the elements "check if in FIRE" → "pull bolt to rear" were joined as the "charge" tactical subgoal, and "place in SAFE" → "pull trigger" became the "release bolt" subgoal. Similarly, "open cover" was connected to "remove ammo belt" because the ammo belt was located under the cover. The next two elements, "raise feed tray" → "remove chambered rounds," were joined because the firing chamber was accessed by lifting the feed tray.

While attempting to connect tactical and strategic subgoals, it became clear that the four elements from "place weapon in SAFE" to "remove chambered rounds" were all directly related to removing ammunition. However, the act of charging the weapon was indirectly related to removing ammunition by virtue of the fact that it was necessary to put the bolt in the rear position to get at the firing chamber. Thus, another tactical subgoal ("remove ammo") was formed separately from the charge subgoal. Both were related to the superordinate Unload subgoal. For the second subgoal, the element "close cover" and the subgoal "release bolt" were both connected to Return because they both related to restoring the weapon to its initial state.

DISCUSSION

The hierarchies obtained through analysis appear to be valid representations of task goal structures. More important than their face validity, however, is their relevance to training practices and their heuristic value to further research. Some possible applications of the structures are discussed below.

Training Implications

These analyses identified useful task information that might help the soldier learn and remember a procedure. Even though these knowledges are conceptual in nature, we are not advocating a return to the traditional passive lecture approach to convey them. Active practice must be a central feature of any procedural training approach. What we are suggesting is that instruction be designed to encourage appropriate memory organization within a performance context.

One possible approach can be termed a "part-task" training strategy. According to this technique, instructors demonstrate the procedures of the strategic subgoals separately, providing a short explanation of each subgoal objective. Soldiers then practice each subprocedure separately before attempting the procedure as a whole. Part-task training should assure that soldiers organize procedural elements into appropriate subgoal units. Also, the information about subgoal objectives should help the soldiers interrelate the various task goals.

Another approach, which could be used in conjunction with the part-task strategy, is to train soldiers to associate subgoal names with the appropriate subprocedures. Then the names can serve as mnemonic aids for recalling the procedural elements. For instance, the 20 elements of the Immediate Action task would be cued by the names for the five strategic subgoals: Fire, Clear,

Hand Cycle, Reload, and Fire. Similar mnemonic techniques have already been incorporated into Armor training. For example, cavalry scouts are taught the acronym SALUTE for remembering the information that should be given in a spot report: Size, Activity, Location, Unit, Time, and Equipment. However, there is an important difference in the two approaches to mnemonics: The immediate action cues are related to task goal structure, whereas the spot report acronym is essentially irrelevant to task content. Shea (1977) demonstrated that task-relevant verbal labels were more effective mnemonic aids than irrelevant labels. Thus, we expect the subgoal names to be more effective mnemonic aids than task-irrelevant acronyms.

Research Extensions

According to the present methods of analysis, the analyst derives task structure using his or her own knowledge of task goals and a few rules of cognitive processing. Resnick (1976) argues that such rational task analyses can provide good preliminary representations of task requirements. Nevertheless, there were some problems with the rational approach presented here. The cognitive rules were so general that the analysis depended largely on the analyst's subjective interpretation of task goals. Moreover, even with more objective techniques, the task structure derived by an analysis is not necessarily the same as the structure actually used by the soldier to remember the procedure. In order to find out how learners accomplish tasks, Resnick suggested that empirical analyses of performance be used to follow up rational analyses.

A potential empirical technique for determining task structure has been outlined by Friendly (1979). His method, called proximity analysis, is based on the assumption that items that are grouped together in memory tend to be clustered together at recall. Thus, the pattern of response proximities reveals the organization of memory. The analysis is a two-step process that starts with obtaining estimates of temporal or ordinal proximity on an item-by-item basis. The proximities are then subjected to a numerical cluster analysis to determine the hierarchical structure. The product of the analysis is a graphical representation of memory structure. Although proximity analysis has been applied to free recall of verbal lists, there is no reason why it cannot be applied to verbal recall of a procedure. Results from such an objective empirical analysis may lead to modifications of our initial conceptions of task structure to more closely match the organization actually used by the performer.

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APPENDIX

HIERARCHICAL STRUCTURES FOR ARMOR TASKS

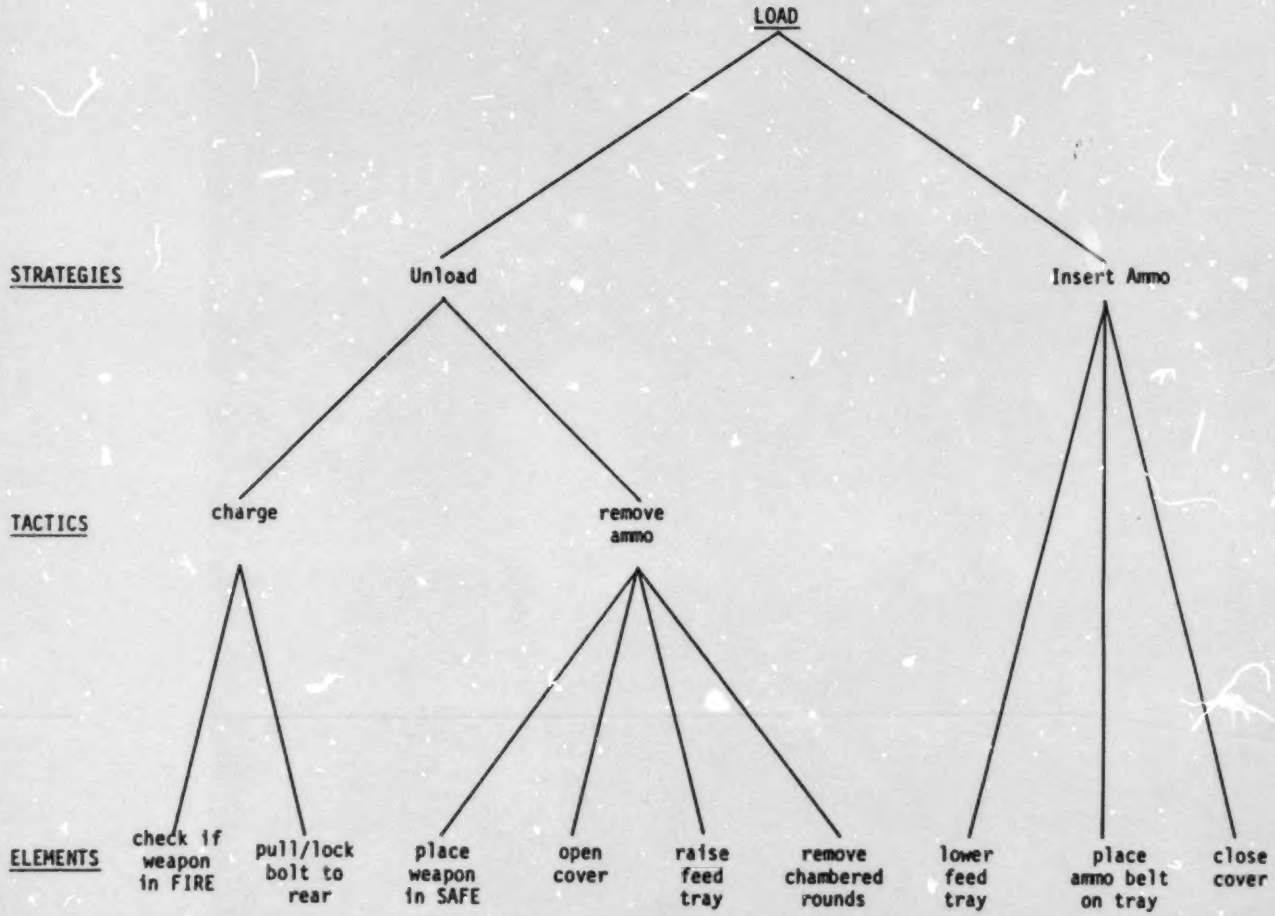

Figure A-1. Hierarchical goal structure for Load the M240.

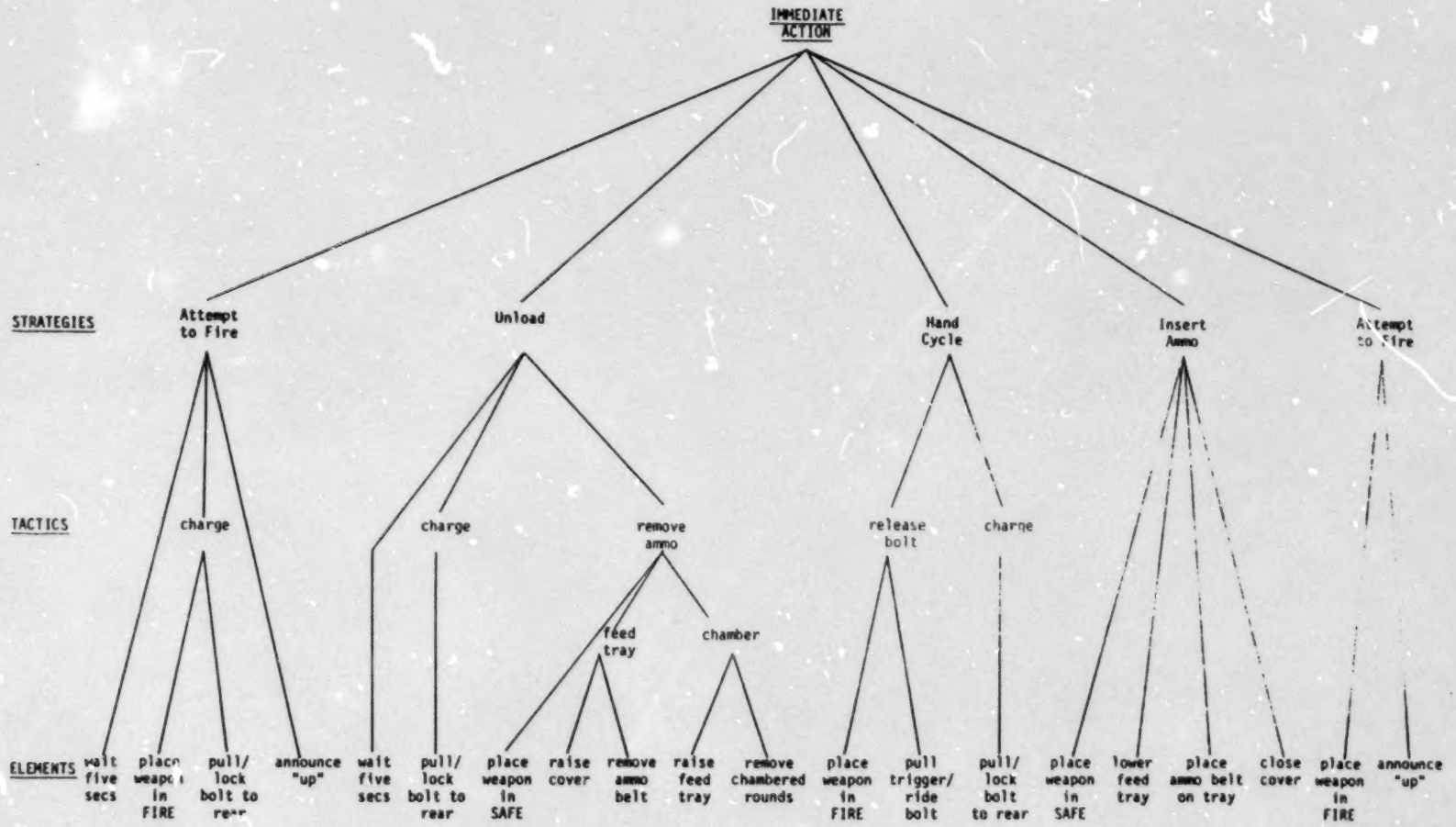

Figure A-2. Hierarchical goal structure for Immediate Action on the M240.

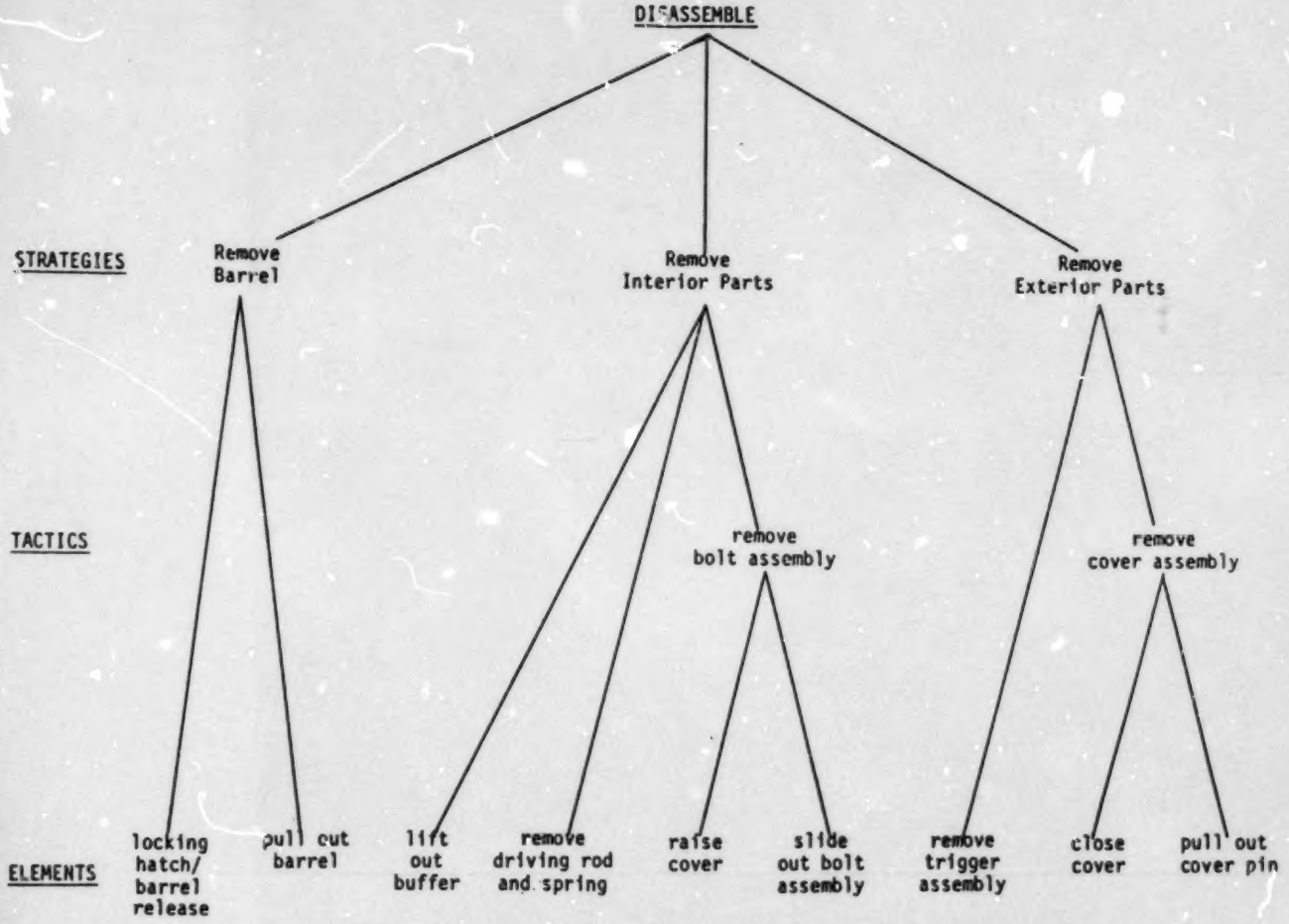

Figure A-3. Hierarchical goal structure for Disassemble the M240.

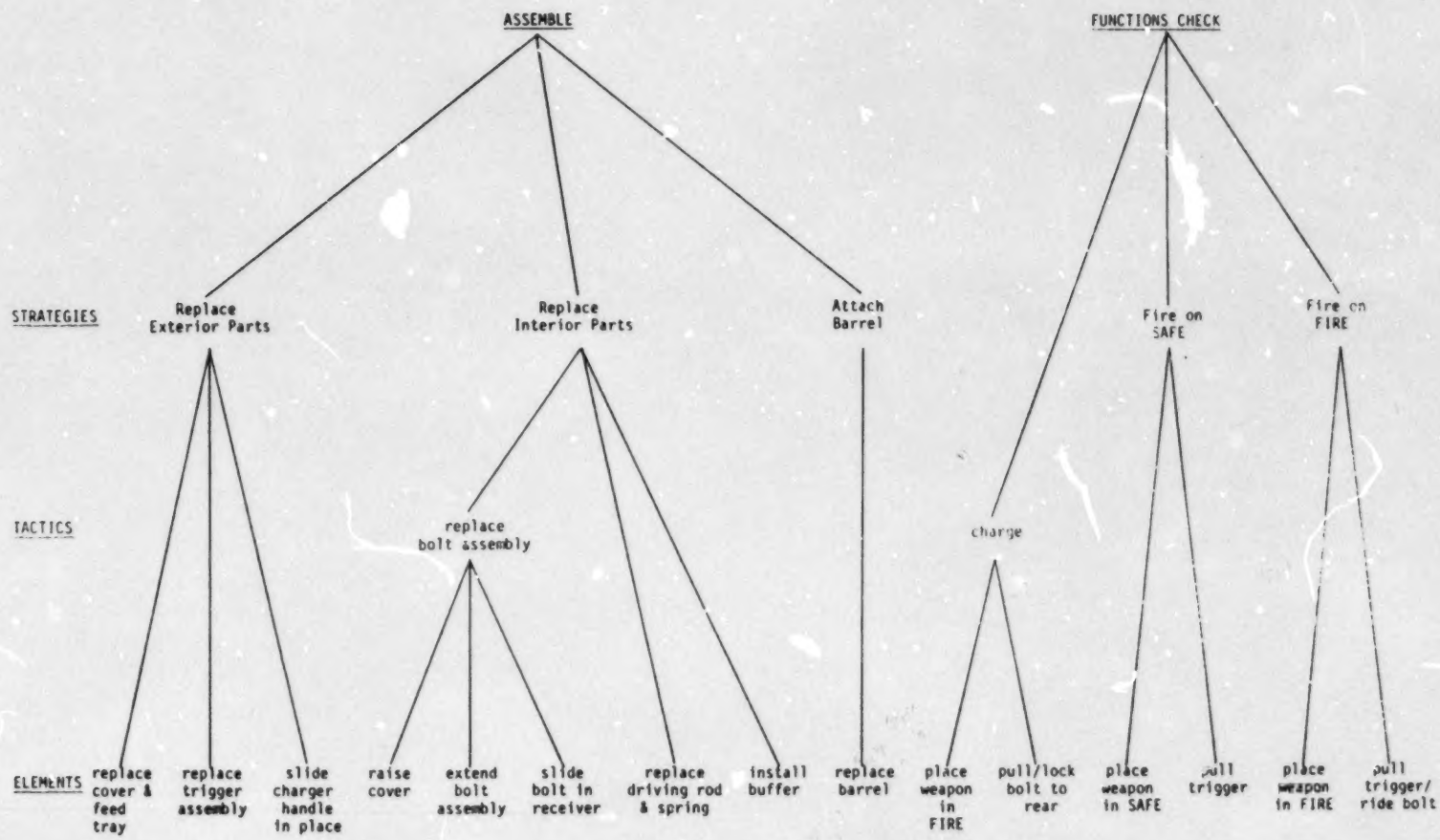

Figure A-4. Hierarchical goal structure for Assemble/Functions Check the M240.

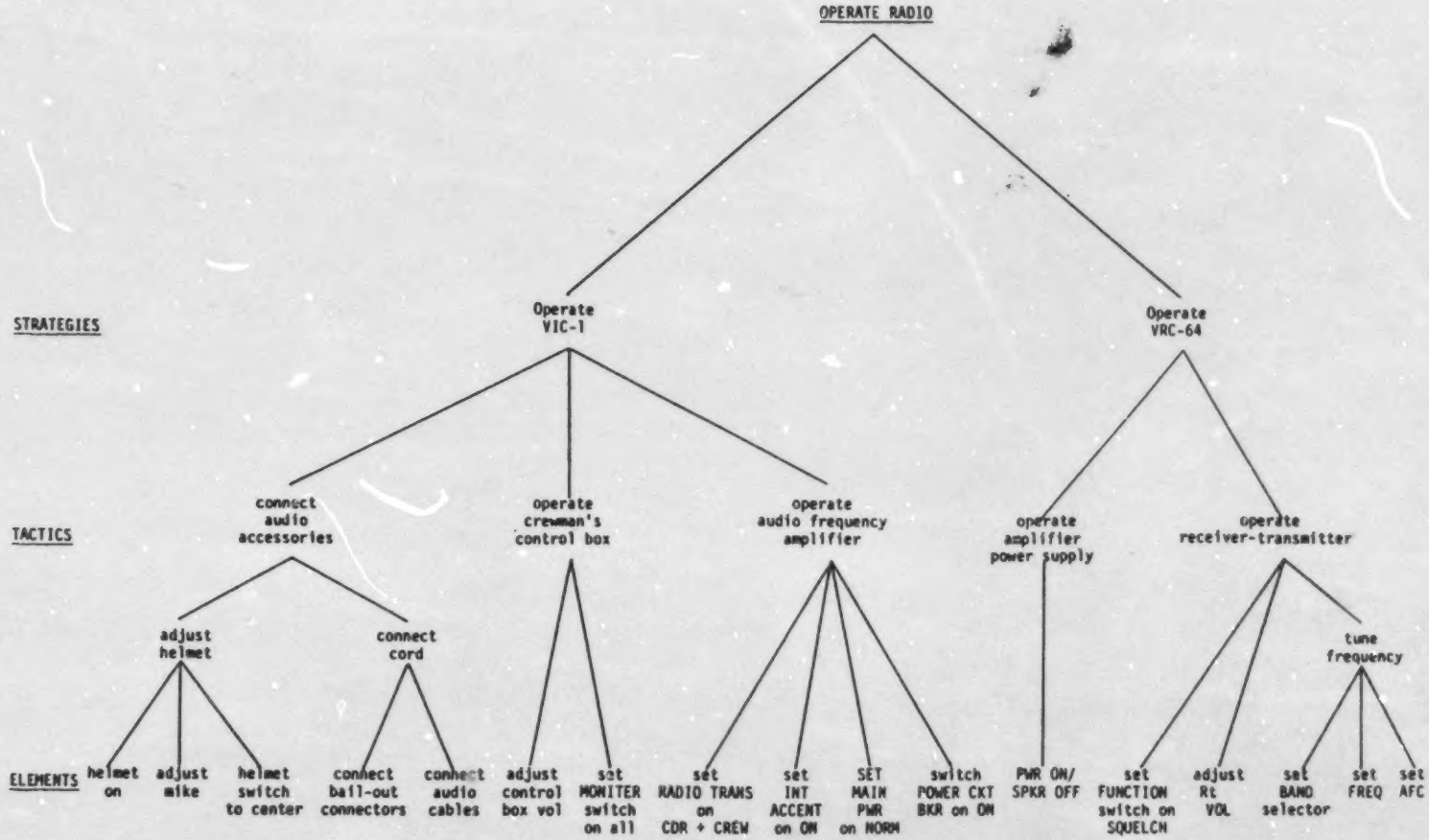

Figure A-5. Hierarchical goal structure for Operate the AN/VRC-64.